THE UNIVERSITY OF ALBERTA

QUALITY FACTORS IN VACUUM-PACKED SWEET CORN

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF FOOD SCIENCE

EDMONTON, ALBERTA

SPRING, 1969

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled

QUALITY FACTORS IN VACUUM-PACKED SWEET CORN

submitted by Kanaan Khalifa in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The conventional non-agitated process of 250°F for 35 minutes caused a severe darkening of the color of the vacuum-packed sweet corn. A marked decrease in this caramelized darkening of the corn was obtained with an agitation process of 250°F for 12 minutes at 10 r.p.m. Agtron reflectance values for whole kernels processed by the non-agitated and agitated processes averaged 24.2 and 49.8 respectively for plant run corn. When the agitation process was used some varietal differences in color were found but differences in color attributable to stage of maturity or length of time elapsing between harvesting and processing were not found. Agtron values recorded for the experimental packs of plant run corn processed by the above agitated process, showed this corn to be as bright in color and free from evidence of caramelization as the commercial Ontario packed corn with which it was compared.

Analytical tests in which Alberta and Ontario vacuum-packed corn were compared show that the latter corn had a consistently lower alcohol insoluble solids content and a higher sucrose sugar content. These results indicate that the Alberta corn was picked after it had passed the stage of optimum quality and that the Ontario processor has added

a brine containing a larger quantity of added sugar than is customarily added.

Flavor panel assessments of vacuum-packed corn confirm previous research reports that additional sugar in the brine increases flavor acceptability. The corn packed in brine containing 15% sugar and 2% salt was highly preferred over corn packed in brines with less added sugar content. The increased addition of sugar caused a slight increase in caramelized color defect.

Freezing point determinations of the juice expressed from corn kernels were found to be highly correlated with other accepted methods of determining the optimum harvest time.

ACKNOWLEDGEMENTS

The project was supported by funds made available through the Agricultural Research Trust and was carried out using the facilities provided by the Department of Food Science. The author gratefully acknowledges financial assistance received in the form of a Graduate Research Assistantship.

The author particularly wishes to thank Professor F.W. Wood for his guidance in planning and supervising the project and for checking the manuscript.

Sincere appreciation is expressed to all the academic and non-academic staff of the Department of Food Science for their help throughout the work. The author is also grateful for the facilities and assistance of the staffs of the Cornwall Canning Company of Taber and the Canada Department of Agriculture Research Station at Lethbridge.

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I. INTRODUCTION

Research into factors that influence the quality of both fresh and processed sweet corn has been extensive in the corn growing areas of the United States of America. These studies have been principally directed to the development of methods for assessing the stage of corn maturity that will insure optimum flavor and tenderness in the fresh and processed product. In the development of these methods a factor of paramount importance has been the applicability of such procedure to field and processing plant conditions.

In Canada and especially the province of Alberta, there is a paucity of published analytical information on the quality of sweet corn both fresh and processed. The irrigated areas of Alberta in the vicinity of Lethbridge and Medicine Hat have long been recognized as suitable for growing high quality corn but little, if any, information is available on research studies of this valuable crop and consequently there is no information available for comparing the quality of Alberta corn with corn grown in other sweet corn growing areas of Canada, such as Ontario and British Columbia.

In 1965 the attention of the Department of Food Science at the University of Alberta was drawn to the

existence of a defect in vacuum-packed sweet corn which was described as "a caramelization color" defect. This defect caused the processed corn to have a dull dark yellow color instead of the bright yellow color normally associated with the fresh corn and placed this popular type of processed product in a poor competitive position with corn produced in other areas of Canada. Because of the lack of research data on the corn produced in this area there was considerable speculation on the principal cause of the defect. The effect of heat on the development of a caramelized flavor and color is well established but the possibility of other contributing factors could not be easily assessed.

The present investigation was undertaken to determine the effect of thermal processing on the caramelization defect and also to assess the influence of other processing factors such as variety, stage of maturity and storage time between harvesting and processing. This study also provided an opportunity to obtain other analytical data on the composition of Alberta processed vacuum-packed sweet corn that could be compared with the information obtained on a popular brand of vacuum-packed sweet corn from Ontario. The considerably lower total sugar content of Alberta processed corn indicated that the brine used by other processors had a higher sugar content. This prompted a limited study of the flavor acceptability of a higher sugar content in Alberta processed corn. The

analytical results on the processed Alberta corn also showed a higher alcohol insoluble solids content than normally found in a high quality product. Recent studies by Kaldy (1966) show that the climatic condition in the Lethbridge area contributes to a higher fiber content in green beans. The possibility that climatic factors might also contribute to the high alcohol insoluble solids content of corn in this area was investigated by the application of a number of the standard tests developed for determining the stage of maturity of corn. Among the tests applied to corn at several stages of maturity was a freezing-point determination of the juice expressed from the kernels.

II. REVIEW OF LITERATURE

Parameters of canned food quality such as color, flavor and texture are related not only to the quality of the raw product, but also to the method of processing. Any improvement in the canning process which will decrease the time required for heating and cooling is of paramount importance Weld *et al.* (1951).

Vacuum pack processing of the yellow varieties of whole kernel sweet corn has met with outstanding success. Essentially, the vacuum procedure is based on the principle that the creation of a high vacuum in the can permits the use of a minimum amount of added water or brine. This liquid, in the absence of other gases, vaporizes at the container surface to transfer heat to food particles and this eliminates the need for filling the can with brine for rapid heat transfer. The water soluble vitamins and minerals are contained in a small quantity of brine and are not wasted according to Wade *et al.* (1950).

Andrew and Weckel (1965) stated that the quality of sweet corn depends on individual taste, the processing method, the hybrid, and the stage of maturity at harvest.

Stage of Maturity

The stage of maturity is one of the most important single factors governing the final quality of a given variety

of corn. During maturation there is a continual increase in the solids content with a consequent decrease in moisture, which may be used to provide an index of maturity. Scott, et al. (1945), Appleman and Eaton (1921), Culpepper and Magoon (1924 and 1927) and Appleman (1921) were first to initiate substantial enquiries into the relation of the maturity at harvest to the quality in the can. Appleman stated that corn should be picked in the milk stage, and that the length of time the kernels remained in prime condition depended upon prevailing climatic factors, of which the most important was temperature. He concluded that the optimal picking time for whole kernel sweet corn coincided with kernel moisture in the range of 75% to 78%, and that this range represents two to four days in the field, depending upon temperature at time of maturation. The appearance of silk as a reference point was used by Culpepper and Magoon (1924) on both yellow and white varieties of sweet corn. They reached the conclusion that prime condition is attained, depending upon variety, between the nineteenth and twenty-fourth days. These times correspond with moisture levels which are closely related to the optimal range recommended by later workers. The moisture content of kernels was found to decrease from 88.6% to 63.0% from the tenth to the twenty-fifth day from silking, giving an average rate of

loss of 1.7% per day. The same workers developed a simple puncturing device for the rapid determination of maturity. The force required to puncture individual kernels showed direct correlation to the time after silking. Later (1927) Culpepper and Magoon stated that two groups of factors influence the quality of canned sweet corn. One factor is the chemical constituents of corn, their nature and relative proportion and the other has to do with harvesting time and cannery practice. They investigated several factors in each of these groups including the toughness of the kernel, the sugar content or sweetness, the moisture content, the compactness of the insoluble material in the endosperm, and the flavor. The importance of any factor depends upon the degree of variation which occurs; e.g., if sugar is the only significantly variable factor, the variety having the highest sugar content is the most desirable, and if the outstanding variation is in the tenderness of the pericarp, that corn in which it is too tough is the least desirable. They put sugar or natural sweetness next after texture and tenderness in order of importance among the factors affecting quality in canned sweet corn. In their experience corn containing 5.5% sugar is the most desirable. They also found that the highest point of sweetness occurs just before the corn is ready to harvest. Smith (1940) stressed the maturity-quality relationship of

canned sweet corn and found that the moisture content of the kernels was the most reliable index for the time of picking. He attempted unsuccessfully to develop a rapid means of estimation of maturity through measurement of electrical conductivity. Cameron et al. (1942) used a modified oven drying procedure for moisture content determination, by employing a high drying temperature to shorten the time involved. Abnormal changes occurred during drying, but the method was found to be rapid and reliable. They confirmed that the refractive index determination was a comparatively accurate measure of the stage of maturity when applied to freshly harvested sweet corn. The value of the refractive index as a measure of maturity was also investigated by Scott et al. (1945), using a modified Abbe-type refractometer and accurate temperature control. They reported progressive increases in the solids content and decreases in moisture content as the corn advanced in maturity. Michell and Lynch (1951) found a close relationship between percent moisture determined by the standard oven method and the rapid refractometer procedure. They reported that the difference between the refractometer value and the standard oven method is about 1.5% moisture.

The stage of maturity has been determined by specific gravity measurements. Burton (1922) indicated that the specific gravity could be used as a method for differentiating

between mature and immature corn. Culpepper and Magoon (1928) determined the specific gravity of totally removed kernels of sweet, dent, flour, flint and waxy types of corn. They found that the density of the kernel varied with the stage of maturity and with the type of corn. Lee et al. (1942) determined the specific gravity of frozen corn by weighing the thawed whole kernel corn in air and then in solutions and obtained high correlation coefficients when the specific gravity values were correlated with organoleptic values. As a result of their study they stated that fancy frozen whole kernel corn would have a specific gravity falling within the range of 1.080 to 1.118; rejection due to immaturity could be 1.079 and lower and rejection because of over maturity, 1.119 or higher. Gould (1952) used a modified National Potato Chip Institute potato hydrometer to measure the specific gravity of raw sweet corn and with an 8-pound sample established specific gravities for grades of canned corn. Crawford and Gould (1957) evaluated the specific gravity of sweet corn using three different techniques, they found a good relationship between the specific gravity of the fresh cut corn and the processed product, and also between fresh cut and blanched whole kernel sweet corn.

Kertesz (1934) developed the alcohol insoluble solids method for determining the maturity of peas. Jenkins in the same year applied it to sweet corn and found that the alcohol

insoluble solids determination was a good indicator of sweet corn maturity. He proposed a maximum of 20.5% alcohol insoluble solids for grade A, 23.0% for grade B and over 23% for grade C whole kernel canned corn. Jenkins and Sayre (1936) found that the percentages of alcohol insoluble solids serve equally well as indices of the maturity of canned whole kernel sweet corn. They stated that the maturity and tenderness were directly proportional to scores assigned for flavor on the same samples.

The expression of the sap of the plant tissue, for determinations of the physico-chemical properties of the plant tissue has long been recognized. Andre (1906) appears to be the first to express the sap from untreated leaves for measuring the concentration of the solutes by determining depression of the freezing point. Dixon and Atkins (1913) introduced the procedure of freezing the leaves in liquid air before subjecting them to pressure to express the sap. Their results indicated that the volume of sap expressed from frozen leaves was larger than could be expressed from unfrozen leaves. Newton et al. (1926) have described a method of grinding the plant tissue and expressing the fluids at low pressure. Several other investigators have used this method for determining the composition of the sap. Kramer and Smith (1946) adapted this principle of the expression of tissue

sap in the development of the succulometer, which is a simplified hydraulic press. They stated that succulence is approximately equal in accuracy to the moisture test on the raw corn and the alcohol insoluble solids test on canned corn for determination of maturity. However, the succulence test is much more rapid and simpler than either of the latter tests. Later Kramer and Guyer (1949) concluded that succulometer and moisture tests give very satisfactory estimations of the quality of fresh unprocessed corn.

Kramer (1952) developed a test for the evaluation of the maturity of sweet corn called a tri-metric test which is based on the moisture content, pericarp content, and kernel size. The results obtained indicated that the test predicts the quality of processed corn accurately, regardless of variations caused by varietal or climatic differences. Subsequently, Kramer (1952a) substituted the alcohol insoluble solids test for the moisture test in the "New tri-metric test" for canned corn quality. His results indicated that the moisture test is the most accurate measure of raw corn quality and he also found that for the processed products the alcohol insoluble solids test is the most accurate measure followed by succulometer, and pericarp tests.

Bailey and Bailey (1938) concluded that the pericarp decreases in thickness as the corn advances in maturity, but the resistance to mechanical puncture was markedly increased with advancing maturity as shown by the puncture test.

The natural sweetness is determined by the stage of corn maturity. Culpepper and Magoon (1927) stated that a high sugar content is desirable in sweet corn for canning and contributes much to the quality of the canned product, but it is not always associated with flavor or quality. According to these researchers there are some differences in flavor contributed entirely by variety. They also observed that as corn approaches maturity the pleasing flavor gradually disappears. Winter et al. (1955) found that the flavor of sweet corn was influenced by variations in sugar content. They indicated that the flavor was influenced more by variations in sugar content when the corn was relatively low in sugar than when the corn was relatively high in sugar content.

Because of the importance of the stage of maturity to corn quality, a number of investigators have studied this problem and developed a number of objective tests in addition to those mentioned above to measure the quality. However, not one of these methods has been found entirely satisfactory for all corn varieties under all conditions of soil, climatic and geographic location. Moreover, no single objective test was found which predicts the quality of sweet corn for processing unless adjustments are made for varietal and climatic differences. It is possible to predict the quality of corn by a combination of tests such

as the tri-metric test, but the principle problem with these tests is that they are time consuming and the fieldman or the processor needs a reliable test with which he can quickly predict the quality of the sweet corn.

Processing Procedure

The quality of the finished product depends not only on the quality of the raw material, but also on the method of processing or the processing techniques. Factors such as time and temperature and the use of vacuum processing have a profound effect on the quality of the finished product. The amount of agitation taking place during processing, heating and cooling must also be considered. The type of agitation is one of the most important factors determining processing time. Three types of agitation have been recognized:

1. Continuous end-over-end rotation.
2. Continuous axial rotation.
3. Intermittent axial rotation.

The efficiency of different agitation processes have been evaluated. Roberts *et al*. (1947) observed that end-over-end and continuous axial rotation produce essentially the same rate of heating. Clifcorn *et al*. (1950),

in their studies on the rate of heat penetration in cans agitated by a variety of methods, indicated that the end-over-end rotation at controlled speeds has superiority over other methods of agitation. The quality factors of foods are more efficiently preserved by the high temperature short-time processes. The end-over-end rotation also greatly improves the quality of the product by reducing the processing time.

The vacuum packing procedure has made a significant impact on the processing of high quality canned vegetables. Whole kernel corn has proved to be the most popular of the vacuum-packed vegetables. The preparation of vegetables for vacuum packing is practically the same as for brine packing. The two methods differ mainly in the brining and seaming operations. In the vacuum packing method only enough brine is added to produce sufficient steam vapor to permit rapid heat penetration and ensure an adequate sterilizing process that will give a product of better quality. Clifcorn et al. (1950) found that vacuum packed corn in a 307 x 306 size can processed at 260°F for five minutes was greatly improved in quality compared with the previous techniques and resembled fresh blanched corn. The processing temperature in their end-over-end rotation process ranged from 212 to 300°F. They reported that the maximum practical temperature for the agitation

processes for most products should not exceed 270°F, not because of localized "burn on" or "over cooking" of the product in the can, but from a consideration of establishing adequate processes as affected by the variations in packaging conditions, which in turn influences the rate of heat transfer from can to can. Vetter _et al_. (1957) described direct steam injunction for the sterilization of whole kernel corn. They used a pressure chamber and the steam was directly injected into number 2 cans. The corn was processed for 75 to 200 seconds at 268°F. The samples were graded organoleptically one day after processing and the results indicated that there was no significant difference between the steam sterilized corn and frozen corn. After storage for four months at room temperature the samples still rated high in color and texture, however, an off-flavor developed due to the activity of enzymes which were not completely inactivated by this high temperature short-time procedure.

Hodge (1953) stated that caramelization occurs when polyhydroxycarbonyl compounds (sugar and polyhydroxycarboxyclic acids) are heated to a relatively high temperature. Thus in order to avoid caramelization the heat applied to any product containing sugar should be carefully controlled.

The Brine Composition

The sugar and salt content of the brine added to corn has a profound effect on the flavor but the color of the finished product is only slightly effected.

Weckel *et al.* (1960, 1961, 1962) and Lenz and Weckel (1967) indicated, that within the range 3.0% to 8.7% of sugar in the brine added to canned whole kernel corn, the consumer preferred the corn processed with the highest level of sugar. The color of the corn packed and stored under different storage temperatures (40 to 90°F) was slightly but not significantly effected, but in the case of peas the Hunter color difference meter L values decreased with an increase in the concentration of sucrose and sodium chloride. The use of increased levels of added sugar in the canned corn resulted in an increase of the soluble and total solids of the corn, but was without effect on alcohol insoluble solids.

Winter, *et al.* (1951) concluded that quality in sweet corn is dependent on sweetness, flavor, tenderness and succulence. Tenderness and succulence are used to determine the picking maturity at which the sugar content is near maximum. Culpepper and Magoon (1927) stated that a high sugar content does not always ensure high flavor, and they suggested that the ratio of water soluble to total polysaccharides may affect quality and compactness with which the polysaccharides are laid down.

The National Canners Association, Bulletin 26-L (1966) recommends the following procedure for conventionally vacuum-packed whole kernel sweet corn in 307 x 306 cans.

Initial temperature	Processes		
	240°F	245°F	250°F
70 to 100°F	55 min	45 min	35 min

The following processes are suggested when the cans are agitated:

Can Size	Agitation	Processes at 250°F
307 x 306	end-over-end 10 r.p.m.	12 min
307 x 306	Continuous axial (continuous cocker)	12 min
307 x 306	Intermittent axial	14 min

ANALYTICAL PROCEDURES

The following methods were used throughout this investigation, unless otherwise specified.

1. Color Comparison

The color of differently treated corn was measured with an Agtron color difference meter equipped with a mercury vapor light and a green filter having maximum absorption at 546 mm.

Forty g of drained kernel corn was weighed in the sample cup. A pressure of 2 lbs. was applied for one min. to obtain a uniform sample distribution in the bottom of the cup. The color values were then read directly.

2. Alcohol Insoluble Solids

The Food and Drug Administration method, as modified by Desrosier *et al*. (1958), was used. The results were expressed as percent solids on a dry basis.

3. Moisture Content

The vacuum oven method (A.O.A.C. 1965) was used. The sample size ranged from 10 to 15 g.

4. Sugar Determination

Sucrose, total reducing sugar, and total sugar were determined by the method of Ting (1956) as modified

by Furuholmen *et al.* (1963).

5. Fiber Content

The fiber content was determined by the A.O.A.C. method (1965).

6. Tenderness

Shear values measurement were determined with a Lee-Kramer shear press, Model SP-12 equipped with electronic recording attachment. The proving ring used was 3000 lbs., and the sensitivity was selected to give a full-scale recorder deflection for a 1000 lbs. load. The speed of the stroke was constant for all samples. Sample size was 40 g, uniformly distributed in the shear cell.

7. Succulometer Test

The method of Kramer and Smith (1946) was used. Briefly the procedure was as follows:

The corn sample was soaked in twice its volume of water for exactly 5 min. After draining for 2 min. on an 8 mesh screen a 100 g sample was weighed for testing. This sample was then loaded into a specially designed hydraulic press and subjected to a pressure of 500 lbs. per square inch. The amount of liquid squeezed out of the corn in 3 min. represents the succulence of the corn.

8. Pericarp Content

The method used was that of Kramer *et al*. (1949), as modified by Gould *et al*. (1951). A 50 g sample was used in place of the recommended 100 g sample. The results were expressed in percentage of pericarp.

9. Specific Gravity

The method used was that of Crawford (1957). The sample, approximately 100 g, was placed in a basket constructed of 30 mesh wire and weighed in air. The sample was then rapidly weighed in water to avoid diffusion of solids into the water. Some investigators blanch the corn on the cob in boiling water to gelatinize the starch before weighing. In the present investigation the water was replaced after each weighing. There was no indication that any measurable difference took place before weighing. The specific gravity was calculated as follows:

$$\text{Specific Gravity} = \frac{\text{Wt. of corn in air X specific gravity of water}}{\text{Wt. of corn in air - Wt. of corn in water}}$$

10. Freezing Point

A Fiske milk cryoscope[1] was used. It is necessary to remove the insoluble starch particles which initiate

[1] Fiske milk cryoscope.
Fiske Associates Inc.,
Bethel, Connecticut, U.S.A.

crystallization and make measurement of the freezing point impossible. Two methods were used to remove these particles. In one method the starch was precipitated with a 1 to 1 solution of lead acetate. The precipitate was removed by centrifuging at 1500 r.p.m. for 10 min and filtered through an ordinary filter paper. In the other method the starch was separated without prior precipitation by centrifugation at 15,000 r.p.m. for 20 min in a Sorval superspeed centrifuge[2].

All analytical tests were done in duplicate unless otherwise specified.

[2] Sorvall Superspeed
RC2-B
Ivan Sorvall Inc.,
Norwalk, Connecticut, U.S.A.

SECTION I

THE CARAMELIZATION DEFECT IN VACUUM - PACKED WHOLE KERNEL SWEET CORN

EXPERIMENTAL METHODS

The effect of the following factors, as possible contributors to a caramelized color defect of vacuum-packed sweet corn, was studied:

1. Processing time and temperature
2. Stage of maturity
3. Corn varieties
4. Holding time between harvesting and processing

Source of corn

The corn used in these experiments was grown in the irrigation district of Alberta in the vicinity of Taber.

1. Processing time and temperature

In a review of processing procedures for vacuum-packed sweet corn, it was apparent that there was little, if any, research reported on the effect of heat on the caramelization of the corn during processing. Roberts and Sognefest (1947) reported that as the can size and

the length of the conventional process increase the outer portions of the corn become darker. Thus, there exists an appreciable color difference within a single can of still processed vacuum-packed corn. The corn at the can center has a reasonably good color while the corn at the can walls appears dark and dull. However, a bright color, uniform throughout the can, is obtained when the corn is vacuum-packed in a large can and is given an agitation process.

Processing procedures

Regular plant runs of corn of no particular variety were used in these experiments. The corn is referred to as plant corn (P.C.). The processing procedures were as follows:

1. The corn was processed in the regular plant retorts (nonagitated) and referred to as P.C. 1. The processing time and temperature was 250^{o}F for 35 min.

2. The same corn was processed in a Berlin Chapman laboratory basket retort model D-3013B at 250^{o}F for 12 min. using 10 r.p.m. end-over-end agitation. This process is referred to as P.C. 2.

3. The same processes as above in 2, except the time was 9 and 8 min. and the temperature was 260^{o}F, are referred to as P.C. 3 and P.C. 3A respectively.

In each of these processes 12 - 307 x 306 standard cans for vacuum-packed sweet corn were processed. All of the corn in these experiments was processed without delay after filling and seaming the cans. The come-up time in the laboratory retort was approximately 4-5 min., and the processed product was quickly cooled to 100°F and stored at 40°F until final testing, usually six months later.

2. <u>Stage of maturity</u>

With the assistance of the field staff of the Cornwall Canning Company of Taber, corn was carefully selected to represent the following stages of maturity: 1. Immature, 2. Mature (unsuitable for fancy grade).

The following varieties were selected for this study:

(1)	NK 75 North King	210	regulars
(2)	Mellow Gold	211	regulars
(3)	Seneca	213	regulars
(4)	Queen Ann	214	regulars
(5)	XP 2047		experimentals
(6)	EX 5280		experimentals

Preparation

Only one variety of corn was processed per day to permit expeditious preparation of the corn for processing because of the manual preparation.

The ears were carefully selected for uniformity and the husking, trimming, and washing was done manually. A commercial corn cutter especially equipped for this purpose was set aside for cutting the kernels from the cobs. The corn was then washed to remove chaff, husk, cob or silk. After draining it was carefully weighed into 307 x 306 cans 10.75 to 11.25 ounces (305 to 319 g) per can, and 60 ml of brine was added. The cans used throughout this investigation had standard "C" enamel coating.

Filled cans were seamed with the regular plant vacuum seaming equipment at a vacuum of 28 inches of mercury. The corn was processed at 250°F for 12 min., with end-over-end agitation (P.C. 2), cooled to 100°F and stored.

3. Corn Varieties

The following varieties were selected in this study: E 3455a, 64-2160, P 2144, Golden Early Pack, Hydrid G 101, and Seneca 200.

The preparation of the corn, the filling, seaming and processing (P.C. 2) were the same as that described above.

4. Holding Time Between Harvesting and Processing

Only one variety of corn, EX 5280, was used to determine the effect of holding time before processing. Ears were selected from a pile of corn on the unloading slab being held overnight and processed without delay. The following day P.C. 1 samples were obtained from the commercial pack which had been held overnight for comparison purposes.

RESULTS

1. The Effect of Processing Temperature and Time

The Agtron values clearly show the effect of the more severe process used by the cannery on the carameli-zation of the corn in the results that are summarized in Table 1. The values obtained on the corn kernels ranged from 13.8 to 31.5 and averaged 24.2 for the corn processed at 250°F for 35 min without agitation. On the other hand the less severe heat treatments, made possible by agitation, resulted in much less caramelization, as is shown by the higher Agtron values, averaging 49.8, when the corn was processed at 250°F for 12 min. Processing at 260°F for 8 or 9 min, with the same agitation procedure, produced slightly lower Agtron values, indicating somewhat greater caramelization, particularly when the

Table 1. The effect of processing condition on caramelization.

Type of Corn	Processing Condition	Agtron Values			
		Whole Kernels		Blended Kernels[2]	
		Range	Ave.[1]	Range	Ave.[1]
Plant Corn	$250^{o}F$ - 35 min no agitation	13.8-31.5	24.2	42.5-61.5	51.0
Plant Corn	$250^{o}F$ - 12 min - 10 r.p.m.	40.8-56.5	49.8	66.5-87.5	78.3
Plant Corn	$260^{o}F$ - 9 min - 10 r.p.m.	36.0-49.5	42.4	59.0-79.0	69.2
Plant Corn	$260^{o}F$ - 8 min - 10 r.p.m.	35.0-50.0	44.9	65.0-85.0	77.0
Ontario Corn	Not known	37.0-69.3	47.9	69.0-88.0	77.0

(1) With the exception of the process $260^{o}F$ - 8 min, in which 3 tests were averaged, the number of tests averaged were 6 or 7.

(2) The corn and brine were blended in a Waring blender.

Table 2. The effect of stage of maturity on caramelization - processing 250°F for 12 min, 10 r.p.m. agitation

Corn	Stage of Maturity	Agtron Values	
		Whole Kernels	Blended Kernels
5280	Mature	53	77.5
	Immature	53	71.0
213	Mature	50	73.5
	Immature	49	72.0
210	Mature	46	64.5
	Immature	42	58.0
211	Mature	44	70.0
	Immature	42	68.0
214	Mature	43	61.0
	Immature	44	70.0
2047	Mature	42	64.0
	Immature	46	55.0

processing time was 9 min. The Agtron values of the Ontario processed corn ranged from 37.0 to 69.3 and averaged 47.9 indicating that this corn was similar in color and caramelization to the experimental corn processed at 250^{O}F for 12 min at 10 r.p.m. The Agtron values obtained on the kernels that were blended in a Waring blender parallel those values obtained on the whole kernels.

The differences in the color resulting from the more severe heat treatment is clearly shown in the colored photographs of Plate 1. Here it is evident that the agitated process at 250^{O}F for 12 min is much less severe than the plant process of 250^{O}F for 35 min, without agitation. It is also clearly evident that the agitated process produces a product with a color as good, if not superior, to the Ontario processed corn.

2. The Effect of Stage of Maturity

Cobs of corn from six varieties were selected to represent immature and mature stages of ripening. This corn was cut from the cobs and prepared for canning manually. The process used was 250^{O}F for 12 min with agitation at 10 r.p.m. The Agtron values obtained are summarized in Table 2. These results show that there was no essential difference in the Agtron values of mature and immature kernels of corn. However, the results obtained with the

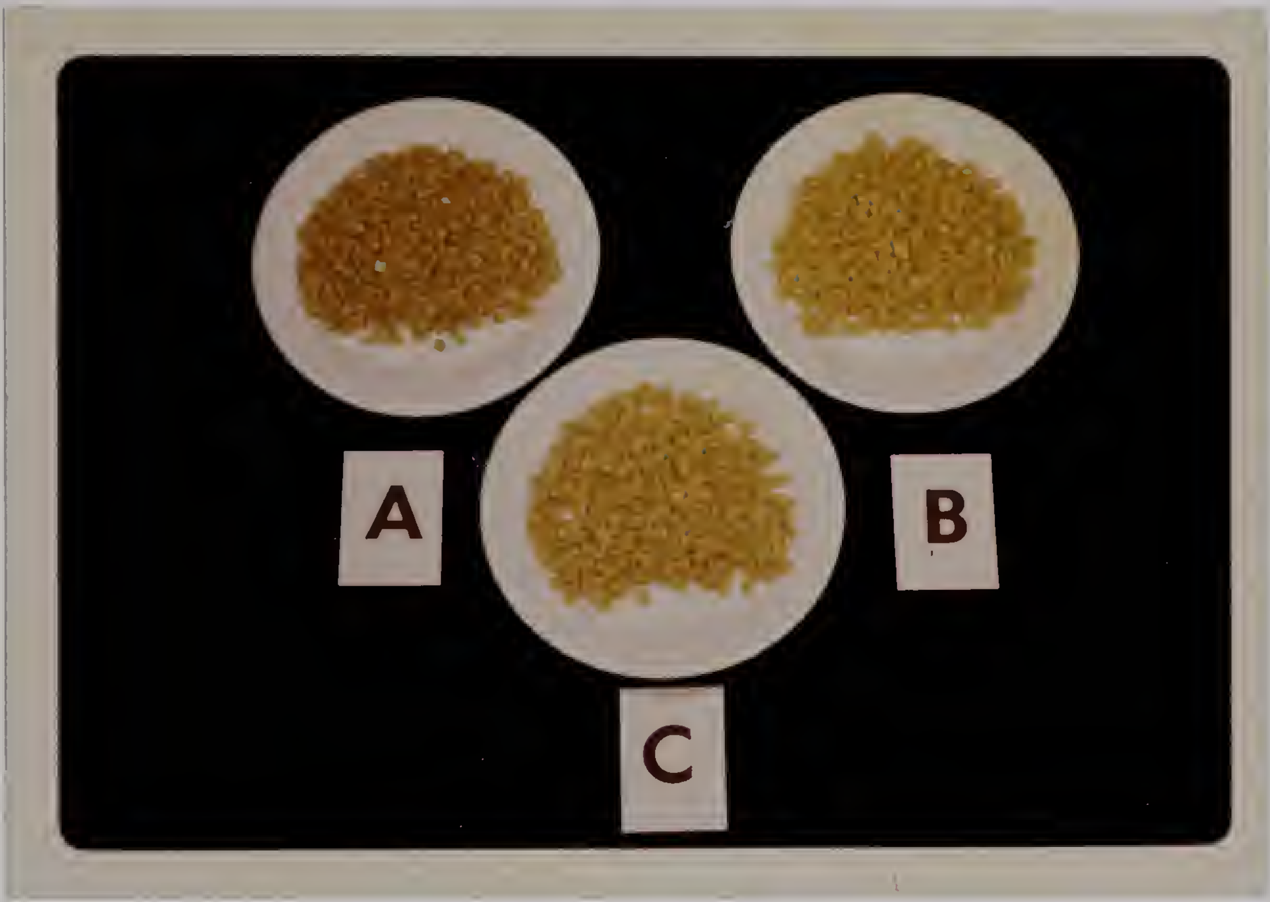

Plate 1. The Effect of Processing Temperature and Time on Caramelization.

A. Plant Corn - Process at 250°F for 35 min without agitation.

B. Plant Corn - Process at 250°F for 12 min with 10 r.p.m. agitation.

C. Ontario processed corn - Process unknown.

blended kernels show lower Agtron values and indicate a darker color for the immature corn in five out of six comparisons.

3. The Effect of Variety

In order to determine whether the variety of the corn processed influences the degree of caramelization during processing, a number of the standard varieties grown in the Taber area, as well as some experimental varieties grown at Taber by the cannery and the Canada Department of Agriculture Research Station at Lethbridge, were compared. The process used was 250°F for 12 min with agitation at 10 r.p.m. The Agtron values obtained are reported in Table 3. In general the values are similar to those obtained with the same process and reported in Table 1. However, the Agtron values of 37 obtained, on variety Sc. 65-67 was considerably lower and the value of 51 for variety Sc. 200 was considerably higher than that obtained from the other varieties. The similarity of the color of three of these corn varieties is shown in the photographs of Plate 2.

4. The Effect of Holding Time Between Harvest and Processing

One lot of corn was processed on arrival at the cannery and another lot of the same variety of corn was held

Table 3. The effect of variety on caramelization - process 250^{o}F for 12 min with 10 r.p.m. agitation

Corn	Agtron Values	
	Whole Kernels	Blended Kernels
E 3455 A	43	71
64-2160	46	80
SC-65-67	37	74
P 2144	40	76
Golden Early Pack	46	82
G101	44	78
Sc 200	51	82

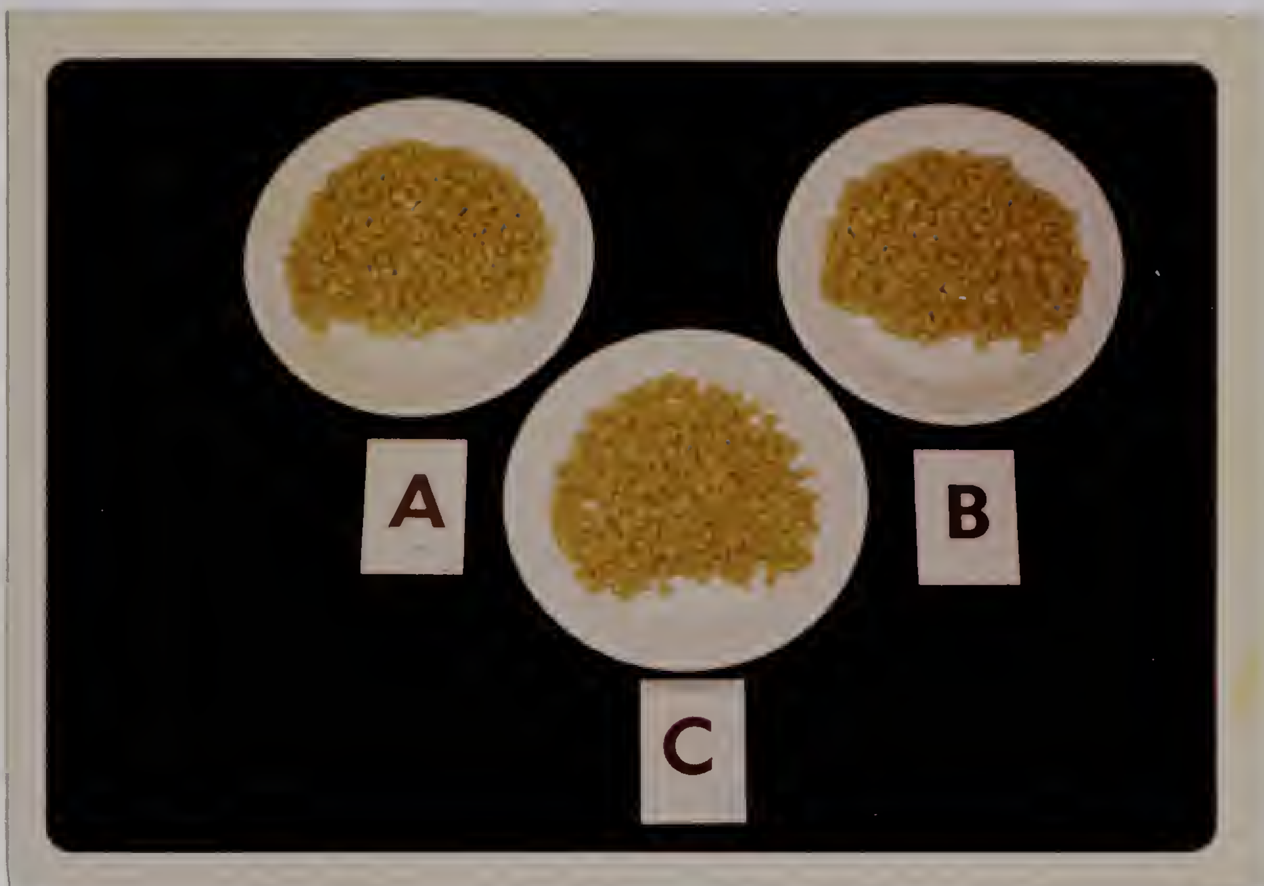

Plate 2. The Effect of Variety on Caramelization - Corn Processed at 250°F for 12 min with 10 r.p.m. agitation.

A. Variety G101.
B. Variety Sc 200.
C. Ontario processed corn.

in a pile overnight before processing. The results of the color evaluation of the corn processed from these two lots are summarized in Table 4. These data show that there was essentially no difference in the Agtron values of the corn processed before or after holding overnight.

DISCUSSION

The results obtained in this investigation clearly show that the process being used in Alberta canneries for the processing of vacuum-packed sweet corn, 250°F for 35 min, is definitely detrimental to the color of the product. Ball (1938) and other investigators have clearly shown that methods of increasing the rate of heat penetration, which would permit High-Temperature Short-Time (HTST) sterilization process, would be beneficial to the quality of heat processed foods. Roberts and Sognefest (1947) reported that white varieties of corn have not been successfully packed by the vacuum method because of the excessive darkening of the corn by the conventional non-agitated process. It is apparent from the results obtained in the present investigation that the yellow varieties also darken considerably from non-enzymatic browning or carameli-zation which occurs when the product is subjected to excessive thermal treatment and cannot be avoided in parts

Table 4. The effect of holding time between harvest and processing on caramelization.

Variety of Corn	Holding Time	Processing Temp. and Time	Agtron Values	
			Whole Kernels	Blended Kernels
5280	Held Overnight	$250^{o}F$ - 12 min	52	86
5280	Held Overnight	$260^{o}F$ - 9 min	43	76
5280	Fresh	$250^{o}F$ - 12 min	53	77
5280	Fresh	$260^{o}F$ - 9 min	40	68

of the product when the heat penetration is slow. Roberts and Sognefest have shown that white varieties of corn are successfully processed with a pleasing bright appearance when agitation processes of equivalent sterilizing values were used. Clifcorn _et al._ (1950) were among the first to show, through end-over-end agitation of cans during processing, that HTST processes greatly enhance the retention of the vitamin thiamine and improve the quality characteristics of food, including color retention. The results obtained in the present investigation confirm that the agitation through end-over-end processing at 250°F for 12 min was very effective in the reduction of caramelization and when used with Alberta yellow varieties of corn produced a product equivalent in brightness of color to the best vacuum-packed sweet corn available on the market. This does not preclude the use of other methods of agitation processes such as axial rotation, which may, under proper operating conditions, produce equivalent results.

When the color of whole kernels of immature and mature corn were compared with an Agtron color comparator there was no essential difference detected. When similar comparisons were made on samples blended by grinding them in a Waring blender, the immature corn was shown to be darker in five out of six comparisons. This difference

which is apparently caused by the settling out of suspended particles has no relevance in the present investigation, which is concerned with whole kernel corn. Other investigators, Estmond et al. (1950) and Henry et al. (1956) reported color differences between immature and mature corn. The failure to confirm these results in the present investigation may lie in the definition of immature and mature stages of development. In the present investigation the difference in maturity was apparently not as great as that reported by these investigators and this may have accounted for the small differences found.

The quality of processed fruit and vegetable products is dependent primarily on two factors: (i) the inherent characteristics of the edible portion and (ii) the external factors, which include handling methods and processing features. Kientz et al. (1965) reported large differences in the percentage of sugar found in corn varieties. A variety Super-Sweet contained 8.6% of total sugar while another variety Sugar King contained only 3.9%. Steinkraus, and MacDonald (1967) processed dried corn of different varieties after dehydration. A variety Illinois Chief was quite different from the other varieties in that it darkened excessively during processing because of higher sugar content. The corn varieties compared in the present investigation showed some differences when they were processed with an agitated process - 250°F for 12 min at

10 r.p.m. The Agtron color values ranged from 37 to 46 units, for Golden Early Pack and variety 64-2160 respectively (Table 3). The variety Golden Early Pack had the highest sugar content of the varieties compared (Table 10) but the variety 64-2160 did not have the lowest sugar content. It must be recognized that the depth of the normal yellow color is a factor that has to be taken into consideration in addition to the possible effect of caramelization influenced by a higher sugar content.

The results in this investigation show no difference in the extent of caramelization darkening between corn processed immediately after arriving at the cannery and after holding overnight, when processed at 250°F for 12 min at 10 r.p.m. The rapid loss of sugar in corn stored any length of time without cooling, especially at high ambient temperatures, is well known. Appleman and Arthur (1919) reported that sweet corn stored one day at 86°F lost 50% of the total sugar, while the loss at 32°F was only 8% for the same storage time. The failure to detect a caramelized color difference in the present study may be caused by the cold night time temperature in southern Alberta during the sweet corn processing season which extends approximately from September 1st to 15th.

SECTION II

SOME ANALYTICAL DATA - CHEMICAL AND PHYSICAL - OF ALBERTA VACUUM-PACKED SWEET CORN

EXPERIMENTAL METHODS

The review of literature showed that the composition of sweet corn in different corn growing areas has been thoroughly investigated. However, there is very little, if any, information reported on the composition of Alberta sweet corn. During the course of these studies on the caramelization defect of Alberta vacuum-packed sweet corn, an opportunity was presented to investigate the chemical and physical properties of Alberta sweet corn and compare this analytical data with that obtained on a popular brand of Ontario processed corn.

RESULTS

In order to evaluate the quality of the corn processed in this investigation and compare it with Ontario processed corn, the moisture content, soluble solids of the brine, sugar content, tenderness and fiber content were determined by the standard testing procedures outlined under experimental methods. These data are presented in Tables 5, 6,

7, 8, 9 and 10. The data summarized in Tables 5, 6 and 7 show the composition of the product obtained from plant run corn in which the variety was not identified. The results indicate that there is no apparent difference in the composition of the corn when it was processed by the different processing procedures used, except that there appears to be a slightly lower shear press value as a consequence of processing in the more severe processes, namely 250°F for 35 min and 260°F for 9 min. In comparing these results with those obtained with the Ontario processed corn in Table 8, it is apparent that the alcohol insoluble solids, a criteria commonly used to evaluate corn quality, is much higher in the Alberta processed corn. The Alberta processed corn also had lower moisture and sugar contents. The average shear press value of the Ontario processed corn (Table 8) at 745 pounds was considerably less than the average values of 847, 878 and 845 shown in Tables 5, 6, and 7 for the Alberta corn.

The correlation between tenderness (Kramer shear press values) and the fiber content of the corn kernels is summarized in Table 11. The correlations obtained are irregular. The Ontario processed corn and the immature and mature corn of several varieties show high correlation of 0.93 and 0.73 respectively, significant at 1% level. The data of Table 5 in which the corn was of mixed varieties

Table 5. Analytical data for plant corn processed at 250°F for 35 min.

Lot No.	moisture %	soluble solids %	alcohol insoluble solids %	sugar %			maximum shear press lbs	fiber % (wet basis)
				Red.	sucrose	total		
1	75.5	11.7	19.4	0.27	2.73	3.00	-	0.75
2	72.2	13.8	21.6	0.37	2.64	3.01	890	0.95
3	73.6	13.5	20.1	0.30	3.14	3.44	-	0.85
4	72.7	13.0	22.0	0.33	2.98	3.31	-	0.97
5	72.4	12.4	26.4	0.28	3.18	3.46	840	0.75
6	73.3	12.2	23.9	0.27	3.32	3.59	780	0.75
7	74.2	14.0	21.3	0.26	3.93	4.19	880	0.79
Ave.	73.4	12.94	22.1	0.30	3.13	3.43	847.5	0.83

Table 6. Analytical data for plant corn processed at 250^{o}F for 12 min with 10 r.p.m. agitation.

Lot No.	moisture %	soluble solids %	alcohol insoluble solids %	sugar %			maximum shear press lbs	fiber % (wet basis)
				Red.	sucrose	total		
1	74.5	12.3	20.2	0.21	3.57	3.78	-	0.80
2	73.3	14.4	21.2	0.35	2.50	2.85	925	0.92
3	73.8	13.0	19.5	0.31	3.50	3.81	-	0.93
4	72.5	12.5	21.8	0.29	2.81	3.10	-	0.89
5	74.7	12.6	22.7	0.23	2.50	2.73	840	0.79
6	74.2	13.1	21.7	0.28	3.26	3.54	865	0.78
7	73.9	13.9	19.8	0.22	3.43	3.65	885	0.85
Ave.	73.8	13.1	21.0	0.27	3.08	3.35	878.75	0.85

Table 7. Analytical data for plant corn processed at 260°F for 9 min with 10 r.p.m. agitation.

Lot No.	moisture %	soluble solids %	alcohol insoluble solids %	sugar % Red.	sucrose	total	maximum shear press lbs	fiber % (wet basis)
1	74.3	12.0	20.8	0.24	2.95	3.19	-	0.80
2	74.2	14.6	20.8	0.38	2.51	2.89	-	0.81
3	72.8	13.1	22.2	0.36	2.64	2.96	-	0.90
4	72.9	12.9	22.4	0.29	2.88	3.17	-	0.88
5	73.2	13.1	22.6	0.26	3.22	3.48	840	0.82
6	74.8	14.2	20.5	0.25	3.21	3.67	850	0.77
Ave.	73.7	13.3	21.55	0.30	2.90	3.20	845	0.83

Table 8. Analytical data for Ontario corn - process and variety unknown.

Lot No.	moisture %	soluble solids %	alcohol insoluble solids %	sugar %			maximum shear press lbs	fiber % (wet basis)
				Red.	sucrose	total		
1	77.4	14.6	14.3	0.51	5.47	5.98	710	0.86
2	78.5	14.5	14.6	0.50	6.30	6.80	755	0.85
3	76.6	14.8	15.2	0.19	3.76	3.95	770	0.91
4	78.3	14.6	14.4	0.41	3.63	4.04	700	0.78
5	77.2	14.0	15.7	0.55	5.33	5.88	740	0.86
6	80.1	14.5	14.8	0.43	4.90	5.33	795	0.77
Ave.	78.0	14.5	18.8	0.43	4.90	5.32	745	0.84

Table 9. Analytical data for mature and immature corn of different varieties processed at 250°F for 12 min with 10 r.p.m. agitation.

Lot No.		moisture %	soluble solids %	alcohol insoluble solids %	sugar %			maximum shear press lbs	fiber % (wet basis)
					Red.	sucrose	total		
5280	mature	73.2	14.2	20.0	0.26	3.09	3.35	830	0.94
	immature	74.2	13.5	15.9	0.32	3.61	3.93	760	0.91
213	mature	76.8	15.2	18.8	0.23	3.88	4.11	770	0.81
	immature	78.4	13.8	15.4	0.30	4.22	4.52	765	0.68
210	mature	72.5	17.5	19.1	0.31	3.60	3.91	860	1.01
	immature	77.4	14.8	15.2	0.37	4.11	4.48	760	0.72
211	mature	73.1	15.3	19.6	0.29	3.25	3.45	885	0.59
	immature	79.0	12.8	15.1	0.40	3.52	3.92	885	0.50
214	mature	70.7	17.5	20.2	0.31	3.40	3.71	910	0.81
	immature	74.9	16.0	16.5	0.40	3.50	3.90	867	0.69
2047	mature	71.4	17.2	20.2	0.27	3.58	3.85	910	0.96
	immature	80.8	13.7	11.7	0.35	3.16	3.51	750	0.86
Ave.	mature	73.0	16.2	19.7	0.28	3.47	3.74	861	0.85
	immature	77.5	14.1	15.0	0.36	3.69	4.04	798	0.73

Table 10. Analytical data for experimental varieties processed at 250°F for 12 min with 10 r.p.m. agitation.

Corn Variety	moisture %	soluble solids %	alcohol insoluble solids %	sugar %			maximum shear press lbs	fiber % (wet basis
				Red.	sucrose	total		
355 A	70.6	14.5	22.5	0.33	3.26	3.59	840	1.01
64-2160	71.4	17.2	20.2	0.27	3.81	4.08	550	0.87
Sc 2-65-67	72.9	15.0	18.6	0.36	3.82	4.18	955	0.99
2144	77.9	13.2	14.9	0.34	3.87	4.21	780	0.64
Golden early pack	71.7	14.8	18.8	0.45	4.21	4.66	960	1.26
Glol	73.3	16.2	18.4	0.24	3.56	3.80	940	0.95
Sc 200	74.2	16.3	17.7	0.27	3.51	3.78	760	0.97
Ave.	73.1	15.3	18.7	0.32	3.72	4.04	826	0.96

Table 11. Correlation between Kramer shear press values and fiber content.

Data Compared	Correlation Coefficient
Plant Corn - process 250 $^{\circ}$F - 35 min no agitation	0.66
Plant Corn - process 250 $^{\circ}$F - 12 min - agitation	0.44
Experimental variety - process 250 $^{\circ}$F - 12 min agitation	0.59
Mature and immature corn of different varieties	0.73
Ontario corn - process not known	0.93

and processed at 250°F for 35 min show a correlation significant at the 5% level. Plant corn processed at 250°F for 12 min, with 10 r.p.m. agitation, a much less severe process, did not show a significant correlation.

The results summarized in Table 9 show the analytical data obtained on mature and immature samples of the standard canning varieties of corn grown in the Taber area, which were processed at 250°F for 12 min with agitation at 10 r.p.m. These results show that the moisture content of the immature corn was consistently higher than that of the mature corn for each of the varieties compared. Similarly, with one exception, the total sugar content of the immature corn was also higher. This corn, variety 2047, was so immature in its development, as is indicated by the very low alcohol insoluble solids of 11.7%, that a true comparison was not possible. The shear press values also attest to the greater tenderness of the immature corn. In general the results obtained with the immature Alberta corn are comparable to those obtained on the Ontario processed corn.

The analytical data obtained on some experimental varieties of corn are summarized in Table 10. It is apparent that there was a considerable variation in the results obtained by the analytical procedures that are commonly used to assess the quality of sweet corn namely, moisture content, alcohol insoluble solids, sugar content, and

shear press values. Variety 64-2160 was tenderest according to the shear press value, it also has a reasonably low alcohol insoluble solids content and one of the higher sugar contents. Variety 2144 was also of higher quality by the same criteria and this was particularly evident in the unusually low alcohol insoluble solids content. Variety 355A, on the other hand, was least acceptable by these criteria.

DISCUSSION

It is clear from the results obtained on the plant corn (Table 5, 6 and 7) that the alcohol insoluble solids are higher than was found in the Ontario corn (Table 8). The higher alcohol insoluble solids is paralleled by a lower moisture content. These findings definitely indicate that the corn at this cannery is being harvested for processing at more advanced stage of maturity than the Ontario corn with which it was compared. Another important quality factor difference found was the consistently higher reducing and total sugar content of the Ontario corn. The average reducing sugar content for the Ontario corn (Table 8) was 0.43% compared with averages of 0.3, 0.27 and 0.3% in Tables 5, 6 and 7. The data for total sugar, which includes sucrose, show an average of 5.33 % for the Ontario corn and averages of only 3.43, 3.35 and 3.39% for the Alberta corn. The reducing sugar data, confirm that

the Alberta corn was harvested at a more advanced stage of maturity, but the greater total sugar content of the Ontario corn indicates quite clearly that the brine added to this vacuum-packed corn must contain a higher sugar content that is commonly recommended and actually used in Taber cannery in both the plant processed and experimentally processed corn. Weckel et al. (1960) have shown that vacuum-packed sweet corn, in which the sugar content of the brine was as high as 8.7% was preferred in a consumer survey. In the present investigation, the influence of higher sugar addition to the brine added to the vacuum-packed corn on acceptability preference was investigated.

The results of this study also clearly indicates that Ontario processed corn was more tender than the Alberta corn as shown by the Kramer shear press values. In fact the shear press values of the immature corn (Table 9) indicate that the Ontario corn was apparently harvested at a more immature stage than the corn termed as immature in the present investigation. Comparisons of tenderness (shear press values) and fiber content indicate that a number of factors other than the fiber content may be involved. The results indicate that variety and processing condition may modify the influence of the fiber content on tenderness.

SECTION III

THE INFLUENCE OF BRINE COMPOSITION ON THE FLAVOR ACCEPTABILITY OF VACUUM-PACKED SWEET CORN

EXPERIMENTAL METHODS

A search of the literature revealed that little information was available on the influence of the sugar and salt composition of the very limited quantity (1-2 oz) of brine customarily added to vacuum-packed sweet corn on the acceptability of corn processed in this manner. The only report on the sugar and salt content of vacuum-packed corn was that of Weckel *et al*. (1960). In this research the investigators found in a consumer survey that there was a statistically significant increase in the flavor acceptability when the sugar content was increased to 8.7 percent, the highest sugar content used in this research. This favorable indication of increased flavor acceptability of vacuum-packed corn prompted a limited study of the influence of the sugar and salt concentration of brine on the flavor acceptability of vacuum-packed sweet corn in the present investigation.

Source of Corn

These experiments were conducted with fancy grade frozen sweet corn obtained in bulk from a processor of

frozen corn in the winter months when fresh sweet corn was not available. Initial tests had demonstrated that such corn would be successfully canned by the vacuum-pack method after defrosting. Three varieties previously used in part 1 of this investigation designated by numbers 210, 211 and 214 were obtained for this investigation.

Processing Procedure

The standard vacuum-pack procedure was followed, after the corn was warmed to thaw it, so that it could be readily filled into 307 x 306 cans. The fill per can averaged 310 grams and brine addition was 60 mls. The cans after seaming under a vacuum of 25 inches of mercury (uncorrected) were warmed in a water bath at $180^{O}F$ for 10 min. Retorting was at $250^{O}F$ for 12 min. with end-over-end agitation, 10 r.p.m. followed by cooling to $100^{O}F$ and storage at $40^{O}F$.

Composition of Brine

The composition of the brines used in this experiment are shown in the following table:

Code	% Sugar	% Salt
A1	10	1
A2	10	2
A3	10	3
B1	15	1
B2	15	2
B3	15	3
C1	20	1
C2	20	2
C3	20	3

Organoleptic Evaluation

Taste panels of departmental personnel, many of whom had previous experience in organoleptic evaluation, were used to evaluate the acceptability of the corn samples on a hedonic scale ranging from a score of 1 for an extremely disliked sample to score of 9 for an extremely liked sample. Analyses of variance were made on the data. Treatment means were compared by Duncan's new multiple-range test (Larmond 1967, and Steel and Torrie, 1960).

The panel was advised that corn, processed with a series of brines containing varying amounts of sugar and salt, were to be evaluated.

The preferences for each of the brine composition variations were recorded for each of the three selected

corn varieties on the above described standard hedonic scale.

RESULTS

Analytical Data

The analytical data obtained on the three varieties of corn processed with increasing levels of added sugar and salt are contained in Tables 12, 13 and 14. These data are principally concerned with the resulting sugar and salt content of the corn when the content of the cans, corn and added brine, were blended in the Waring blender. The results show the effect of the added brine on the sugar and salt content of the blended corn for each sugar and salt addition. From these data it is evident that increased sugar contents in the processed corn resulted in lower Agtron readings as indication of a higher degree of caramelization during the processing of the corn.

The increased content of sugar and salt in the added brine is reflected in higher total and soluble solids in the brine following processing. The alcohol insoluble solids content was not affected by the sugar and salt content of the brines. There was also no apparent effect on the pH of the brine.

Table 12. Analyses of canned whole kernel sweet corn - variety 210.

Corn	pH brine	Agtron values	soluble solids %	A.I.S. %	moisture %	sodium chloride %	sugar % reducing	sucrose	total	fiber %
A1	6.60	48.0	13.8	20.0	77.0	0.28	0.33			
A2	6.55	45.5	14.0	19.5	73.6	0.35	0.30	3.09	3.40	0.84
A3	6.55	40.0	14.2	19.4	73.7	0.38	0.31			0.84
B1	6.58	39.5	14.4	19.6	74.5	0.23	0.38			0.84
B2	6.55	43.5	14.7	19.5	74.6	0.35	0.38	3.82	4.20	0.83
B3	6.60	39.0	15.0	19.9	74.0	0.39	0.39			0.85
C1	6.65	37.0	15.0	20.5	73.6	0.21	0.40			0.84
C2	6.80	36.5	15.2	20.3	73.5	0.32	0.41	4.3	4.70	
C3	6.60	35.5	15.4	20.2	73.2	0.40				

Table 13. Analyses of canned whole kernel sweet corn - variety 211.

Corn	pH brine	Agtron values	soluble solids %	A.I.S. %	moisture %	sodium chloride %	sugar % reducing	sugar % sucrose	sugar % total	fiber %
A1	6.58	45.0	12.5	21.1	73.3	0.21	0.32			0.91
A2	6.48	45.5	13.3	21.7	72.7	0.34	0.33	3.07	3.40	0.92
A3	6.53	42.5	13.8	21.4	73.0	0.44	0.34			0.92
B1	6.75	36.0	13.9	21.3	72.1	0.21	0.34			0.92
B2	6.66	36.0	14.0	21.3	72.7	0.32	0.34	4.06	4.40	
B3	6.60	32.0	14.0	21.2	72.3	0.43	0.35			
C1	6.7	38.0	14.2	21.3	71.3	0.26	0.36			
C2	6.68	38.0	14.9	21.3	71.6	0.34	0.37	4.84	5.20	
C3	6.73	38.0	15.1	21.1	70.2	0.44	0.36			

Table 14. Analysis of canned whole kernel sweet corn - variety 214.

Corn	pH brine	Agtron values	soluble solids %	A.I.S. %	moisture %	sodium chloride %	sugar % reducing	sucrose	total	fiber %
A1	6.35	40.0	13.3	22.3	72.3	0.23	0.34	3.49	3.83	0.93
A2	6.58	38.0	13.6	22.2	71.7	0.34	0.34	3.60	3.94	0.93
A3	6.40	36.0	14.1	22.0	72.0	0.43	0.35	3.54	3.99	
B1	6.53	42.0	14.2	21.9	70.9	0.23	0.33	4.11	4.44	
B2	6.55	39.5	14.4	22.0	71.4	0.33	0.36	4.15	4.51	0.94
B3	6.45	38.0	14.6	22.3	71.0	0.43	0.35	4.13	4.48	0.92
C1	6.60	40.0	14.8	22.1	69.8	0.23	0.38	5.23	5.61	
C2	6.65	38.5	15.3	22.5	69.8	0.34	0.40	5.80	6.20	
C3	6.65	36.5	15.6	21.8	69.0	0.45	0.39	5.41	5.80	

Table 15. Analysis of variance and multiple - range test of flavor as measured by the taste panel (variety 210).

Source of Variance	Degrees of freedom	Sums of squares	Mean Squares	F-values
Samples	9	78.11	8.68	4.19**
Panelists	18	119.78	6.65	
Error	162	335.59		
Total	189	533.48		

Means(1) of Hedonic scores:

A2	B3	A3	C2	B2	A1	B1	C3	C1	Control
6.63	6.58	6.47	6.37	6.32	6.26	6.21	5.95	5.79	4.32

** significant at the 1% level

(1) Any two means not underscored by the same line are significantly different at the 1% level of probability

Table 16. Analysis of variance and multiple - range test of flavor as measured by the taste panel (variety 211).

Source of Variance	Degrees of freedom	Sums of squares	Mean squares	F-values
Samples	9	40.14	4.46	2.084*
Panelists	25	189.2	7.57	
Error	225	481.26	2.14	
Total	259	710.6		

Means[1] of Hedonic scores:

B1	C1	C3	A1	B2	C2	A2	B1	A3	Control
6.15	6.15	6.15	6.08	6.00	5.69	5.69	5.58	5.23	5.00

* Significant at the 5% level

[1] Any two means not underscored by the same line are significantly different at the 5% level of probability

Table 17. Analysis of variance and multiple - range test of flavor as measured by the taste panel (variety 214).

Source of Variance	Degrees of freedom	Sums of squares	Mean squares	F-values
Samples	9	29.99	3.33	1.61
Panelists	22	346.89	15.77	
Error	198	408.91	2.07	
Total	229	785.79		

Means of Hedonic scores:	B2	C2	A1	A3	C3	C1	A2	B3	B1
	6.33	6.07	5.93	5.80	5.80	5.73	5.67	5.60	5.43

Samples F - value is not significant at the 1 and 5% level. This indicates the mean rating of the samples are equal or there is no significant difference

Table 18. Analysis of variance and multiple - range test of flavor as measured by the taste panel (variety 210).

Source of Variance	Degrees of freedom	Sums of squares	Mean squares	F-values
Samples	8	54.78	5.72	4.0**
Panelists	20	298.55	14.47	
Error	160	228.54	1.42	
Total	188	563.88		

Means(1) of Hedonic scores:

A1	B2	B3	A2	C1	A3	C2	B1	C3
6.81	6.67	5.91	5.81	5.81	5.71	5.67	5.43	5.24

** Significant at the 1% level

(1) Any two means not underscored by the same line are significantly different at the 5% level of probability

Table 19. Analysis of variance and multiple - range test of flavor as measured by the taste panel (variety 211).

Source of Variance	Degrees of freedom	Sums of squares	Mean squares	F-values
Samples	8	28.32	3.54	2.31*
Panelists	18	191.33	10.61	
Error	144	220.35	1.53	
Total	170	440.00		

Means[(1)] of Hedonic scores:

B2	C3	A3	A1	C2	C1	B3	A2	B1
7.00	6.37	6.00	5.89	5.84	5.79	5.74	5.74	5.63

* Significant at the 5% level

[(1)] Any two means not underscored by the same line are significantly different at the 5% level of probability

Table 20. Analysis of variance and multiple - range test of flavor as measured by the taste panel (variety 214).

Source of Variance	Degrees of freedom	Sums of squares	Mean squares	F-values
Samples	8	23.10	2.89	0.93
Panelists	14	124.12	8.87	
Error	112	348.71	3.113	
Total	134	495.93		

	B2	A1	A3	B1	C1	C3	A2	B3	C2	C3
Means of Hedonic scores:	6.43	6.25	6.05	5.95	5.83	5.72	5.41	5.33	5.31	5.28

Sample F-value is not significant at the 1 and 5% level. This indicates that the mean rating of the samples are equal or there is no significant difference.

Flavor Panel Evaluation

The analysis of variance and comparisons of the means of the hedonic flavor scores for each brine composition by Duncan's Multiple range test (Larmond 1967 and Steel and Torrie 1960) are shown in Tables 15 to 20 inclusive. When the mean scores of the experimental corn were compared with each other and with the mean score of the Ontario processed corn, which was used as a control or standard of comparison, Tables 15, 16 and 17, there was no significant preference for any of the experimental corn treatments, but the experimental corn treatments were highly preferred by the judges over the Ontario corn.

When the hedonic scores of the experimental samples were compared, Tables 18, 19 and 20, the results show that for corn varieties 210 and 211, the corn containing brine with 15% sugar and 2% salt were highly preferred. On the other hand for varieties 210 and 214, the corn processed with brine containing only 10% sugar and 1% abd 2% salt respectively was highly preferred. It should be noted, however, that these corn varieties had a higher natural sugar content than the variety 211 (Tables 12, 13 and 14).

DISCUSSION

Weckel *et al.* (1960) found that when the brine containing sugar ranging from 3 to 8.67% was added to vacuum-packed

whole kernel sweet corn a consumer survey showed a preference for the corn packed with the highest level of added sugar in the brine. The present investigation, with three varieties of corn, confirms this finding and, furthermore, shows that with some corn varieties, 210 and 211, the addition of sugar in the brine of up to 15% was preferred when the salt was 2%. These limited comparisons also indicate that the natural sugar content of the corn reduced the quantity of added sugar required in the brine to insure optimum flavor acceptability.

SECTION IV

TESTS FOR PREDICTING OPTIMUM HARVESTING TIME FOR SWEET CORN QUALITY

EXPERIMENTAL METHODS

It is well established that small changes in the maturity of sweet corn can have a profound influence on the quality of the fresh and canned product. Studies of such an influence have been well documented in the foregoing review of the literature. Methods of assessing the degree of maturity in the field, and also in the processing plant, have received considerable investigation, but no one method developed to date has proved to be entirely satisfactory. So it is not unusual to observe the field staff attempting to arrive at an assessment of maturity and quality by rupturing the kernels of the cob of corn with the thumb nail and examining the extruded juice as an indication of maturity, because of the lack of a suitable rapid testing procedure for both field and plant application.

The literature reviewed revealed that the following tests have been applied, moisture content, specific gravity, alcohol insoluble solids, succulence, and pericarp content. There has not been any reported study of the

suitability of these methods under the conditions existing in Alberta corn fields, that conceivably could be quite different from the conditions existing in other corn growing areas of Canada and the United States. Consequently some of the standard procedures, mentioned above, were applied to corn in the Taber area and the results obtained were compared with a new procedure, the determination of the freezing point, which was brought to our attention by Swipe (1968) who is applying the procedure in New York State. This procedure appeared to have merit as sweet corn is highest in sugar content when the flavor and tenderness are at the maximum acceptability, and furthermore, the quantity of juice required is small and could easily be expressed manually and the present freezing apparatus extensively used to determine the freezing of milk could readily be made portable for making rapid measurement in the field or in a quality control laboratory.

Source of Corn

Four varieties of sweet corn grown in the Taber area for canning and freezing, that were utilized in other sections of this investigation, namely, North King 210, Mellow Gold 211, Seneca 213, and Queen Ann 214, were used in this part of the study.

Harvesting

Ears of corn were selected at intervals to represent four distinct stages in the maturity of the corn, namely, 1. Very immature - not suitable for processing; 2. Immature - kernels in milk stage but still immature for processing; 3. Optimum stage of maturity - best quality for either freezing or vacuum-packing; 4. Over mature - definitely past the stage for processing into fancy grade before use in fresh sweet corn market. The cobs were stored in insulated cooler boxes to maintain them at $30^{\circ}F$ to $40^{\circ}F$ for transport to the laboratory at Lethbridge, where they were stored at this temperature until the tests were completed.

RESULTS

The data obtained by applying several objective methods for determining the optimum harvesting time for sweet corn are summarized in Table 21. According to Kramer (1951, 1952) the moisture content is the most reliable indication of the maturity of fresh corn but moisture determinations are difficult to make under field conditions. Accordingly the moisture test made at each stage of corn maturity was compared with the other objective tests namely, alcohol insoluble solids, succulence, pericarp content, specific gravity and freezing point depression. The correlations

Table 21. The data obtained by various analytical procedures on corn harvested at four distinct stages of maturity.

Corn	Harvest[1]	% Moisture	% A.I.S.	Succl. ml	% Pericarp Sp.	Gravity	Freezing Point °C
210	1st	81.1	12.7	29.3	1.28	1.05	-.88
	2nd	75.0	17.3	24.2	1.64	1.07	-.82
	3rd	74.6	20.6	21.5	1.74	1.08	-.81
	4th	71.7	24.7	17.8	1.95	1.09	-.79
211	1st	78.5	13.9	27.3	1.46	1.06	-.84
	2nd	73.8	18.8	23.5	1.55	1.07	-.82
	3rd	70.2	23.5	17.8	1.90	1.09	-.78
	4th	68.3	26.4	14.6	2.36	1.12	-.73
213	1st	86.0	10.5	34.5	1.06	1.05	-.95
	2nd	78.3	13.4	28.5	1.40	1.06	-.90
	3rd	71.2	22.8	19.8	2.04	1.08	-.85
	4th	69.2	22.4	15.5	2.28	1.09	-.75
214	1st	85.0	11.3	33.5	1.14	1.05	-.99
	2nd	81.7	12.9	30.3	1.21	1.06	-.88
	3rd	70.2	24.6	17.3	2.10	1.09	-.78
	4th	67.2	24.9	12.5	2.39	1.12	-.72

(1) 1st - very immature, not suitable for processing
2nd - immature, kernels in milk stage but still immature for processing
3rd - optimum stage of maturity, best quality for either freezing or vacuum-packing
4th - overmature, past the stage for processing into fancy grade

Table 22. Correlation between pairs of objective quality measurements on sweet corn.

Comparisons	Correlation Coefficients variety 210	variety 211	variety 213	variety 214
Moisture vs. A.I.S.	-0.985	-0.996	-0.965	-0.993
Moisture vs. succulence	0.993	0.984	0.986	0.999
Moisture vs. pericarp	-0.996	-0.894	-0.973	-0.993
Moisture vs. specific gravity	0.985	0.309	0.940	0.940
Moisture vs. freezing point	0.997	0.919	0.895	0.926

between the moisture content and each of the other objective measurements of corn quality are summarized in Table 22. These results show a high correlation between each of testing procedures and the moisture test, for corn varieties 210, 213 and 214. However, the correlation between the moisture content and specific gravity was low for variety 211.

DISCUSSION

The high correlation found between the moisture content and the objective tests for alcohol insoluble solids, succulence, pericarp and specific gravity indicate that these tests are just as reliable as the moisture test to measure the optimum harvesting time for sweet corn. However, all of these tests, which are regarded by many investigators to be reliable measures of optimum harvesting time, are time consuming and require laboratory facilities. The freezing point depression, however, is a simple, rapid and accurate test. It is a more rapid test method than the others that have been proposed and furthermore, only a very small sample of the expressed juice is required after centrifugation of the juice. This test is very sensitive to changes in the sugar content of the juice, which is a very important parameter of corn flavor acceptability.

In the preparation of samples for freezing point determinations, precipitation of the starch with lead acetate followed by centrifugation is necessary before determining the freezing point. All of these steps in the determination are simple procedures that can be carried out rapidly on large numbers of samples. Consequently freezing point determination would appear to have much to recommend it for the determination of the optimum harvesting time for sweet corn.

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